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EPA

Project Summary

Evaluation of Emerging Technologies for the Destruction of Hazardous Wastes

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The objective of the full report is to provide detailed information regarding four innovative alternative technologies demonstration projects for treating and destroying hazardous wastes. Under a cooperative agreement between the U.S. Environmental Protection Agency (EPA) and the State of California, the Department of Health Services (DHS) carried out a pilot-scale test program on the following promising technologies.

1. High Temperature Fluid-Wall	Thagard Research
2. Evaluation of Emission Tests from SunOhio Mobile PCB Treatment Process	Air Resources Board State of California
3. Wet Air Oxidation	Zimpro
4. Evaluation of Emission Tests from Wet Air Oxidation Zimpro Process	Air Resources Board State of California

Discussions of the above processes include project descriptions, results, conclusions, and recommendations.

This Project Summary was developed by EPA's Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

On January 20, 1981, the State of California entered into a cooperative agreement with the Office of Research and Development, EPA, to evaluate selected promising technologies for destroying hazardous waste. The inclusion of a process in the report should in no way be considered an endorsement of the process by either the State of California or the EPA.

High Temperature Fluid-Wall, Thagard Research Company

Summary

The High Temperature Fluid-Wall (HTFW) Reactor was developed originally for the continuous dissociation of methane into carbon fines and hydrogen. This particular process required the generation of stable temperatures above 1,700°C and the prevention of precipitate formation on the reactor walls. This fact has particular relevance to the project herein.

Reactor consists of a tubular core of porous refractory material capable of emitting sufficient radiant energy to activate the reactants fed into the tubular space. The reactor has been built with cylindrical core diameters of 3", 6", and 12" with heated core lengths of up to 72". The core material is designed to be of uniform porosity to allow the permeating of a radiation-transparent gas through the core wall into the interior. The core is completely jacketed and insulated in a fluid-tight pressure vessel. Electrodes located in the annular space between jacket and core provide the energy required to heat the core to radiant temperatures.

To achieve both goals simultaneously, the reacting stream is kept out of physical contact with the reactor wall by means of a gaseous blanket formed by flowing an inert gas radially inward

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through the porous reactor tube (or core). Both high temperatures and high rates of heat transfer are achieved by heating the porous carbon core to incandescense so that the predominant mode of heat transfer is by radioactive coupling from the core to the stream.

Reactor is heated electrically with six carbon resistance heaters. Because of the extreme temperatures encountered in operation of the device, the insulation package consists not of refractory brick but of a radiation shield made of multiple layers of graphite paper backed up with carbon felt. The short residence time associated with the reactor which demands the pulverization of solid feeds also lends itself to a compact system where a reasonably high throughput is seen for a small installation, and portability becomes an attainable design feature.

Four volatile chlorinated hydrocarbons [(dichloromethane; 1,1,1-trichloroethane; carbon tetrachloride; and Freon-12 (dichlorodifluoromethane)] and one nonvolatile chlorinated hydrocarbon (hexachlorobenzene) have been decomposed in the HTFW Reactor in bench-scale tests to assess the applicability of the device for efficient destruction of these particular compounds.

The hexachlorobenzene, loaded onto a solid radiation target, exhibited high (<99.9999 percent) destruction efficiency, while the vapors (which could be heated only by secondary thermal conduction from solid radiation target) exhibited destruction efficiencies related inversely to the compound heats of formation, indicating that vapor-phase reaction temperatures were lower than the solid reaction. Destruction efficiencies ranged from 99.999965 percent for dichloromethane to 84.99 percent for Freon-12. Heat transfer analysis indicated that vapor heating is dependent on the solid particle density, and that efficient heating (and destruction) of vapors can be achieved simply by increasing the particle density.

Results and Conclusions

Chlorinated Hydrocarbon Vapor Samples

The most important conclusion drawn from the work completed is that chlorinated hydrocarbons introduced into the reactor *in the vapor form* are much more difficult to destroy than similar materials loaded onto solids, *given identical residence times and* reactor temperatures.

While the governing factor in the case of the solids was the direct absorption of radiation by the solid surfaces and consequent extremely rapid heating, the governing factor in the case of the vapors was the *conduction* of the heat from the particle surface into the vapor—a much slower process limited in rate by the *thermal conductivity* of the vapor itself.

Thus, as might be anticipated, the temperature levels achieved in the vapors for a given residence time will not, in general, be as high as the temperatures achieved on the solids. The experimental result of this behavior will be that minimum temperatures and minimum residence times for complete destruction of the vapor-phase substances will not be achieved, and that the observed destruction levels will now be critically dependent on the heat of formation of the substance being investigated.

Chlorinated Hydrocarbons Solid Sample

The results for hexachlorobenzene (HCB) in soil are in agreement with HCB results on carbon, thus duplicating both the destruction and analytical methods and further substantiating the conclusion that the solids are rapidly heated and the toxic material effectively decomposed.

Despite some data problems, the fraction of HCB remaining on the solids and in the effluent gases was approximately 10^{-6}, corresponding to a destruction efficiency of approximately 99.9999 percent.

The demonstration of gettering of chlorine (from decomposition of HCB) with calcined lime (CaO) mixed with the soil produced no identifiable results. Since gettering of halogens and sulfur with lime and subsequent fixing into a vitreous slag has been previously demonstrated on numerous occasions with other materials we must conclude that some deficiency in the experimental procedure was introduced (inadequate mixing of the lime in the soil, too low a CaO/Cl ratio for this particular application, etc.). Subsequent experimental work will seek to quantify this parameter which is an important system consideration of on-site disposal.

Air Resources Board's (ARB) Evaluation to Determine Emissions from SUNOHIO's Mobile PCB Treatment Process

Three evaluation tests were conducted to allow determination of emissions from SUNOHIO's mobile PCB treatment process. The mobile unit was tested while treating contaminated oils at three locations: Chevron's USA refinery at El Segundo, California; Pacific Gas and Electric (PG&E) Company's facility at Union City, California; and Maxwell Laboratory's facility in San Diego, California.

PCBs were not detected in samples of emissions taken at two of the tests. However, relatively high benzene and aliphatic hydrocarbon concentrations were measured in the units' uncontrolled exhaust gases. Measured concentrations ranged from 18 to 7,000 ppm for benzene and 700 to 2,700 ppm for aliphatic hydrocarbons. Low process volumetric flow rates resulted in the mass emission rates for benzene and the aliphatic hydrocarbons to values of approximately 0.1 lb/hr. and below. Data from samples taken by the South Coast Air Quality Management District (SCAQMD) staff during the El Segundo test indicate that dioxins and furans are not present above the limit of detectability.

The efficiency of the carbon adsorption control system for preventing emissions to the atmosphere of benzene and aliphatic hydrocarbons was found to have varied from approximately 99 to 30 percent, indicative that carbon adsorption breakthrough occurred. The 30 percent efficiency calculation was based upon concentration measurements from the evaluation test conducted at the PG&E facility.

An alternative control system was tested that utilized an oil fired furnace, a component of the PCBX process, to incinerate the emissions. Furnace exhaust gas samples indicate a general reduction in concentration of compounds measured across the furnace. Benzene and toluene were not detected in the furnace exhaust gas.

Introduction

On December 2 and 10, 1982 and November 30, 1983, the ARB's Engineering Evaluation Branch conducted evaluation tests on chemical processing equipment designed to reclaim transformer oils contaminated with PCBs. The process tested is known as the

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"PCBX" process and was developed by SUNOHIO, a partnership between the Sun Company of Radnor, Pennsylvania and the Ohio Transformer Corporation of Louisville, Ohio. The equipment is installed on two mobile trailers and can be driven to different geographical localities to treat contaminated oils on site. The first test was conducted on December 2, 1982 at Chevron's USA El Segundo refinery. This was a joint venture between SCAQMD and the ARB. The second test was conducted on December 10, 1982 at a PG&E facility in Union City. The third test was conducted on November 30, 1983 at the San Diego facility of Maxwell Laboratory.

The objectives of the evaluation tests were to allow determination of emissions from the unit's vacuum degasser and determination of the efficiency of two prototype emission control systems. One control system consists of an oil mist eliminator in combination with an activated charcoal filter to control emissions from the vacuum degasser's vent pipe. The other control system utilizes an oil fired furnace that is a component of the PCBX process to incinerate the emissions.

Conclusions and Recommendations

Based on the analytical results and staff experience obtained from the ARB's evaluation test conducted on the SUNOHIO PCBX process, the following observations are made:

1. The activated carbon adsorption canister used during testing is not big enough to provide effective emissions control for an extended period of time, the control system should be (1) redesigned to have a larger activated carbon adsorption unit, or (2) revise the maintenance schedule for the present carbon canister to require canister replacement with a frequency commensurate with a demonstrated breakthrough time.
2. If emissions are to be prevented from the carbon canister, the carbon canister breakthrough should be monitored with a continuous analyzer.
3. Based upon the results of this test, the oil fired furnace as a control device appears to be effective.

Results and Discussion

1. Results From the Test Conducted at Chevron's USA El Segundo Refinery

   Results of analyses performed on samples taken from the PCBX process during the ARB evaluation test conducted at Chevron's USA El Segundo refinery indicate that Benzene and C_8-C_{12} hydrocarbons were the predominant components measured in the gases vented directly out of the vacuum degasser during the treatment of transformer oil. Benzene concentrations ranged from 400 ppm to 7,000 ppm and hydrocarbon concentrations from 7 ppm to 1,600 ppm. TRW's analytical results for samples taken at the same location as the ARB, show benzene concentrations exceeding 5,000 ppm and C_5 hydrocarbon concentrations as being 1,400 ppm. TRW results for benzene are in the range of concentrations determined by the ARB and the hydrocarbon concentrations, while not directly comparable to the ARB results, are probably not inconsistent. SCAQMD did not take samples from the vacuum degasser outlet.

   PCBs were not detected above the detection limit of the analytical method for any of the ARB samples taken. TRW also sampled for and could not detect PCBs above the limit of detection for their analytical method (1 ppm).

   As discussed previously, SCAQMD took samples before and after the activated carbon adsorber and analyzed those samples for PCBs, furans, and dioxins. Because they sampled at a different location and the emphasis of their analytical work was different, no direct comparison can be made between the SCAQMD and ARB test results. Test results indicate that furans and dioxins are not present above the detectable limits, less than 4-30 parts per trillion. However, in two samples taken from the centrifuge vent at the inlet and outlet of the carbon cannister, detectable amounts of PCBs were measured; 1.7 (10^{-3}) ppm at the inlet and 8.7 (10^{-6}) ppm at the outlet.

2. Results From the Test Conducted at PG&E's Union City Facility

   Benzene and aliphatic hydrocarbons were the major components measured in the ARB samples taken from the degasser vent during the treatment of PCB-contaminated oils stored in a tank at a PG&E facility located in Union City. The range of concentrations determined for benzene and C_6-C_{12} hydrocarbons was 50 to 950 ppm and 1,900 to 2,700 ppm, respectively.

   Benzene and aliphatic hydrocarbons were also the significant components in the treated vacuum degasser vent gas as sampled at the outlet from the control system's activated charcoal adsorber. The range of benzene concentrations was 600-700 ppm and the range of C_6-C_{12} hydrocarbons was 1,400 to 1,800 ppm. BAAQMD also took samples at the charcoal adsorber outlet and test results showed: a comparable benzene concentration of 840 ppm (average); a comparable C_6-C_{12} hydrocarbon concentration of 1,500 ppm; and total organic and nonmethane organic compound concentrations of 2,600 ppm (average) and 2,400 ppm (average), respectively.

   The control system's charcoal canister was the same one used at the El Segundo test. Results of a comparison between the concentrations determined for the inlet and outlet of the control system are indicative of carbon adsorption breakthrough. The reduction of both benzene and aliphatic hydrocarbons was approximately 30 percent across the control system. PCBs were not detected above the detection limit of the analytical method for any of the ARB samples taken.

3. Results From the Test Conducted at the Maxwell Laboratory in San Diego

   Concentration values for emissions were measured during two distinct phases of the PCBX process: (i) degassing and (ii) dechlorination. Benzene concentrations in the uncontrolled vacuum degasser emissions, measured at the common inlet to both control systems, ranged from 18 ppm to 220 ppm. Toluene was also measured at concentrations ranging from 0.1 ppm to 290 ppm.

   At the outlet from the condenser/carbon control systems, measured benzene concentrations ranged from 10 ppm to 23 ppm and toluene from 0.1 ppm to 26 ppm. Benzene and toluene were not

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measured above the 0.1 ppm limit of detection in the exhaust gases from the combustion control device.

Products of combustion in the furnace exhaust gas were monitored when the furnace was fired on fuel oil only and when it was fired with a mixture of fuel oil and vacuum degasser vapors. When combusting fuel oil only, the following compounds were measured: 75 ppm SO_2, 72 ppm NOx, 9.3 ppm THC, 133 ppm CO, 10.2 percent CO_2 and 9.7 percent O_2. When vacuum degasser vapors were added for combustion in the furnace, measured concentrations were: 78 ppm SO_2, 92 ppm NOx, 24 ppm THC, 200 ppm CO, 10.2 percent CO_2, 9.1 percent O_2, 0.1 ppm benzene and 0.1 ppm, toluene.

Samples taken before and after the control devices were speciated to determine the types of compounds present in the emissions. For comparison purposes, a sample of ambient air was taken. The compounds detected in the ambient sample were all at the part per billion (ppb) level. The magnitude of the other concentration values measured in the uncontrolled and controlled emissions were at the part per million level.

Commercial Demonstration of Wet Air Oxidation of Hazardous Wastes

Summary

Wet Air Oxidation by Zimpro, Inc., is a process which has been used to oxidize dissolved or suspended organic substances at elevated temperature and pressures. The process is thermally self-sustaining with relatively low organic feed concentrations and is, therefore, most useful for wastes which are too dilute to incinerate economically yet too toxic to treat biologically.

The purpose of this project was to demonstrate wet air oxidation of toxic and hazardous wastes at a full-size installation which was located at Casmalia Resources, a commercial waste treater in California. In the operation of the full-scale Zimpro Wet Air Oxidation unit, wastes selected from classified groups of organic wastes were detoxified. These classified groups were: phenolic wastes, organic sulfur wastes, general organic wastes, cyanide wastes, pesticide wastes, and solvent still bottoms wastes. This section contains detail evaluation of these six classified wastes' treatment, the effectiveness of the wet air oxidation unit, and sample analysis of feed and effluent.

Description of Wet Air Oxidation Process

The Zimpro Wet Air Oxidation unit for this demonstration processed aqueous wastes at a designed reactor temperature of 550°F, a designed reactor pressure of 2,000 PSIG, a liquid waste flow rate of 10 GPM, and a compressed air rate of approximately 190 SCFM. In the wet oxidation process, liquid waste, exiting from a high pressure pump, is combined with compressed air and directed through the cold, heat-up side of the heat exchanger. The incoming waste-air mixture exits from the heat-up side of the heat exchanger and enters the reactor where exothermic reactions increase the temperature of the mixture to a desired value. The waste-air mixture exits the reactor and enters the hot, cool-down side of the heat exchanger and, after passage through the system pressure control valves, is directed to the separator. In the separator, the spent process vapors (noncondensible gases) are separated from the oxidized liquid phase and are directed into a two-stage water scrubber-carbon bed adsorber, vapor treatment system.

In the wet air oxidation process, organic substances can be completely oxidized to yield highly oxygenated products and water. For example, organic carbon-hydrogen compounds can be oxidized to carbon dioxide and water, while reduced organic sulfur compounds (sulfides, mercaptans, etc.) and inorganic sulfides are easily oxidized to inorganic sulfate, usually present in the oxidized liquor as sulfuric acid. Inorganic cyanides and organic cyanides (nitriles) are easily oxidized to carbon dioxide, ammonia, or molecular nitrogen. It should be noted that oxides of nitrogen such as NO or NO_2 are not formed in wet air oxidation.

When incomplete oxidation of organic substances occurs, the easily oxidized reduced sulfur and cyanides are usually still oxidized to sulfate and carbon dioxide-ammonia provided a sufficient degree of oxidation is accomplished. However, incomplete oxidation of other organic compounds results in the formation of low molecular weight compounds such as acetaldehyde, acetone, and acetic acid. These low molecular weight compounds are volatile and are distributed between the process off-gas phase and the oxidized liquid phase. The concentration of these low molecular weight compounds (measured as total hydrocarbons (THC) expressed as methane) in the process of off-gas is dependent on their concentration in the oxidized liquid phase, which is determined by the degree of oxidation accomplished, the waste being oxidized, and the influent organic concentration of the waste.

Results and Conclusion

Wet air oxidation of phenolic and organic sulfur classes of waste has been demonstrated at the Casmalia Resources, Inc., full-scale wet air oxidation installation. Oxidation of a petroleum refining spent caustic waste at a process temperature of 515°F (268°C) and a nominal residence time of 113 minutes resulted in 99.77 percent total phenols reduction, 94.0 percent organic sulfur reduction, and 89.3 percent chemical oxygen demand (COD) reduction. Gas chromatographic/mass spectroscopic (GS-MS) analysis identified acetic acid, benzoic acid, and several sulfide derivatives as the major components present in the effluent oxidized waste. Analysis of treated process off-gases indicated a total hydrocarbon (THC) concentration of only 84.5 ppm (expressed as methane).

Oxidation resulted in >99.7 percent sulfide sulfur reduction, 98.8 percent total phenols reduction, and 81.3 percent COD reduction. Sulfide sulfur and total phenols concentrations were reduced to >1.0 mg/l and 66 mg/l, respectively, upon oxidation. Further reduction in residual total phenols concentration would likely be achieved by postoxidation treatment with ozone or hydrogen peroxide.

The raw spent caustic wastewater had a BOD_5/COD ratio of 0.49 compared to 0.64 for the oxidized product indicating a slight increase in biodegradability following oxidation. The oxidized product would likely be easily biodegradable since highly biodegradable materials generally have BOD_5/COD ratios in the range of 0.5 to 0.6. The wastewater pH decreased from 12.6 in the raw waste to 8.7 upon oxidation, likely due to the conversion of reduced sulfur compounds to sulfuric acid.

An eight-hour wet air oxidation demonstration of a general organic wastewater was performed at the Casmalia

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Resources, Inc., full-scale wet oxidation installation on July 28, 1983.

The general organic wastewater was processed continually during the eight-hour wet air oxidation demonstration. During the demonstration period, the wet air oxidation unit was operated at an average reactor temperature of 531°F (277°C), a compressed air flow rate of 190 SCFM and a reactor pressure of 1,515 PSIG. Waste was processed at an average liquid flow rate of 5.0 GPM resulting in a nominal residence time of 120 minutes. Residual oxygen concentrations in the process off-gas averaged 4.1 percent during the demonstration period.

The data indicates the waste to be relatively high strength with a chemical oxygen demand (COD) of 76.0 g/l and a dissolved organic carbon (DOC) concentration of 20,830 mg/l. The raw waste had a pH of 1.9. Very effective treatment of the general organic waste was obtained by wet air oxidation. Oxidation resulted in 96.7 percent COD reduction with the waste COD reduced to 2.5 g/l. A DOC reduction of 96.7 percent was obtained with the oxidized waste having a DOC concentration of 685 mg/l.

Analysis of the off-gas sample indicated carbon dioxide, oxygen, nitrogen, and carbon monoxide concentrations of 12.9, 5.9, 81.2, and 0.3 percent, respectively. Total hydrocarbon (THC) and methane concentrations of 29.1 ppm (expressed as methane) and 10.0 ppm, respectively, were determined for the process off-gas sample.

Treatment of cyanide wastewaters by wet air oxidation has been demonstrated at the Casmalia Resources, Inc., full-scale wet air oxidation installation. The wet air oxidation demonstration was performed on July 29 and August 18, 1983 during a combined six-hour period of steady state operation.

The wastewater processed during the wet air oxidation demonstration was a mixture of cyanide wastes generated by various metal plating processes. Laboratory screening tests performed by Zimpro, Inc., indicated the individual wastes contained in the wastewater mixture to be treatable by wet air oxidation and compatible with respect to materials of construction.

During the combined demonstration period, the wet air oxidation unit was operated at an average reactor temperature of 495°F (257°C), a compressed air flow rate of 190 SCFM, and a reactor pressure of 1,220 PSIG. Waste was processed at an average liquid flow rate of 7.5 GPM, resulting in a nominal residence time of 80 minutes. Residual oxygen concentrations in the process off-gas averaged 7.1 percent during the demonstration period. The analyses indicate the composite raw waste to be a typical high strength cyanide waste with a cyanide concentration of 25,390 mg/l, chemical oxygen demand (COD) of 37.4, g/l and pH of 12.6.

Wet air oxidation resulted in very effective treatment of the cyanide waste. The cyanide concentration of the raw waste was reduced to 82 mg/l, representing a cyanide reduction of 99.7 percent. A COD reduction of 88.8 percent and a dissolved organic carbon (DOC) reduction of 88.4 percent were obtained by wet air oxidation. COD and DOC concentrations in the composite oxidized waste were 4.2 g/l and 1,710 mg/l, respectively.

The scale formation which occurred in the oxidation unit during the cyanide demonstration period is reflected by the total ash data. The composite raw waste had a total ash concentration of 112.9 g/l compared to only 77.4 g/l for the composite oxidized waste. Since the ash is expected to pass through the oxidation unit as inert material, the data indicates as much as 35 g/l of inert solids were deposited in the oxidation system during treatment of the cyanide waste.

Analysis of the off-gas sample indicated 1.5 percent carbon dioxide, 8.5 percent oxygen, and 82.8 percent nitrogen. Carbon monoxide was not detected in the off-gas sample. A total hydrocarbon (THC) concentration of 61.1 ppm (expressed as methane) and a methane concentration of ' 0 ppm was determined for the process off-gas sample.

Wet air oxidation of four pesticides—dinoseb, methoxychlor, carbaryl, and malathion—was evaluated in a full-scale demonstration at Casmalia Resources, Casmalia, California, on March 28, 1984. Since wastewaters containing relatively high concentrations of a variety of pesticides were not easily available, the above compounds were spiked into an acidic distillate wastewater which had previously been processed in the Casmalia wet air oxidation unit.

Prior to the full-scale pesticides wet air oxidation demonstration, bench scale autoclave oxidations of a variety of pesticides had been evaluated. Greater than 99 percent destruction was observed for seven pesticides, including the four subsequently demonstrated in the Casmalia full-scale unit.

Removals of the four pesticides ranged from 98.0 to greater than 99.8 percent. Analyses of pesticides in the feed and effluent composites were by gas and liquid chromatography.

COD, BOD_5, and DOC removals were quite similar to results obtained during oxidation of the acidic distillate waste alone. COD, BOD_5, and DOC removals of 95.3, 93.8, and 96.1 percent were observed. Carbon dioxide, oxygen, nitrogen, and carbon monoxide concentrations of 14.2, 3.5, 79.0, and 0.7 percent, respectively, were observed. Total hydrocarbon (THC) and methane concentrations of 153 ppm (expressed as methane) and 61.9 ppm, respectively, were determined for the process off-gas sample.

Wet air oxidation of a solvent still bottoms type waste was evaluated in a full-scale demonstration at Casmalia Resources, Casmalia, California, on March 29, 1984. The wastewater was processed continuously during the eight-hour wet air oxidation demonstration.

Soluble chloride analyses for feed and effluent indicated 7,860 and 505 mg/l, respectively. These data indicate material in the feed causing a positive interference in the chloride analysis. Oxidation of this material resulted in an apparent decrease in soluble chloride. This behavior is frequently seen in the wet air oxidation of industrial wastes.

Soluble fluoride increased from 7.5 to 42.7 mg/l upon oxidation, likely due to the destruction of fluorinated organic compounds. This fluoride content was not observed in previous bench scale screening of this wastewater. Fluoride levels much higher than this may not be acceptable in the Casmalia wet air oxidation unit because of corrosive effects on titanium system components.

Carbon dioxide, oxygen, nitrogen, and carbon monoxide concentrations of 11.8, 3.8, 81.2, and nil percent, respectively, were observed. THC and methane concentrations of 217 ppm (expressed as methane) and 80 ppm, respectively, were determined for the process off-gas sample. However, on-line off-gas THC measurements indicated increasing THC concentrations throughout the demonstration run as the vapor phase activated carbon adsorption bed became exhausted.

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Air Resources Board's Evaluation Test Conducted on a Wet Air Oxidation Process to Treat Hazardous Wastes

Summary

The California Air Resources Board (ARB) conducted six evaluation tests on a wet air oxidation unit manufactured by Zimpro, Inc. The unit designed to treat toxic wastes is installed and operated at a Class I waste disposal facility managed by Casmalia Resources and located in Casmalia, California. The test results of the four category wastes, namely—phenols, sulfides, acid organics, and cyanides—are discussed in the full report.

The ARB evaluation tests were initiated in response to a request by Santa Barbara County Air Pollution Control District for emission data with which to properly establish and assess the wet air oxidation unit's waste processing capabilities and the effectiveness of the air pollution control devices.

Results and Discussion

1. Wet Air Oxidation Process
   Wet air oxidation appears to be an effective method for reducing the concentration of liquid phase cyanide and phenol compounds. Cyanide concentrations measured at the inlet and outlet of the wet air oxidation process were 46,300 parts per million by weight (ppm W) and 6.94 ppm W, respectively. Inlet and outlet phenol concentrations were 18,700 micrograms per milliliter (μg/ml) and 2.35 μg/ml. The reduction in concentration for both compounds treated by the wet air oxidation process was over 99 percent.
   However, wet air oxidation of acid-organics was somewhat less consistent. Two sets of inlet-outlet samples were taken across the process with one indicating a 64 percent reduction of the initial concentration and the other, a 97 percent reduction. Each value was obtained by ratioing the GC/FID generated total peak areas for an inlet-outlet sample pair taken across the wet air oxidation process. When the output sample's GC/FID trace was compared to that for the inlet sample, some peaks had disappeared, some were noticeably reduced, and in some instances, new peaks appeared. Because the availability of standards to identify each peak was limited, the ratio of total peak areas was used to give a relative indication of the wet air oxidation process.
2. Condensible, Noncondensible Separator
   With the exception of acid-organics, the amount of noncondensible cyanide, phenols, and sulfide measured at the separator was at the microgram level. The quantity of CN, phenol, and sulfide captured was 3.23 μg, and 713 μg, respectively. These values also represent the prescrubbed gas concentrations at the inlet to the scrubber. The total volume drawn for each sample was 45 cubic feet. A "less than" symbol (<) preceding a value implies that it is below the detection limit of the analytical method with respect to the total volume sampled.
   Noncondensible acid-organic samples taken at the separator were used to identify and semi-quantitate the major organic components present in the gas stream prior to entering the control equipment. The results show that for the treatment of this particular waste, halogenated (bromo-, chloro-) alkenes and benzene appear to be the major compounds in the gaseous effluents from the separator.
3. Scrubber
   The scrubber was effective in removing sulfide from the gas stream but did not afford any greater control advantage for cyanide and phenols than was achieved by the wet air oxidation process.
   The calculated cyanide concentration at the inlet was very low, 0.0025 μg/l or 0.0034 ppm.
   The measured scrubber efficiency for controlling noncondensible sulfide was 93.4 percent. The scrubber reduced the inlet concentration of 0.555 μg/l, or ppm, to 0.037 μg/l, or ppm.
   The outlet cyanide concentration of 0.0026 μg/l, <0.0025 ppm is comparable to the inlet concentration and indicates that the scrubber has no apparent effect on cyanide when this compound is introduced into the scrubber at such low levels.
   It appears that a major portion of the residual phenols and cyanides remaining after the wet air oxidation process is retained in the separator's liquid phase and pumped to the facility's water discharge pond. Any liquid phase reactions that may be occurring are unknown. There is a minimal contribution of cyanide and phenols to the gas phase for control by the scrubber. However, whether the scrubber would be an effective control device at higher inlet concentrations of cyanide and phenols, as might occur during an upset condition, is yet to be determined.
4. Carbon Bed
   The carbon bed was most effective in controlling the discharge to atmosphere of gas phase brominated compounds. The inlet concentration of 450 ppm was reduced to 0.18 ppm at the outlet of the carbon bed, representing a removal efficiency of over 99 percent. Note that these concentration values are order of magnitude estimates based on (a) the qualitative speciation data that identified brominated hydrocarbons as the major noncondensible hydrocarbons present and (b) quantitative analysis that normalized all significant GC peaks to 1,2-dibromomethane, which was the major identifiable compound for which a standard was available. The normalization technique was performed because standards were not available for the other major peaks. A comparison of these values will give a relative efficiency performance of the carbon adsorber.
   The percentage control for cyanide and sulfide was minimal: 17.8 percent and 26.8 percent, respectively.

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The complete report, entitled "Evaluation of Emerging Technologies for the Destruction of Hazardous Wastes," (Order No. PB 86-128 717/AS; Cost: $16.95, subject to change) will be available only from:
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